1996 Temperature Trends and Potential Impacts to Salmon, Delta Smelt, and Splittail

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As part of DWR's Water Quality Monitoring Program, six continuous monitoring multi-parameter stations collect data at various locations throughout the Delta (Figure 1). At one meter below the surface, the following water quality parameters are monitored: water temperature, pH, dissolved oxygen, and electrical conductivity. Data are recorded once per hour from an accumulated average of three samples per second, and the information is telemetered on a real-time basis and posted on the IEP Home Page.

For 1996, water temperatures at the six stations were averaged over a monthly period. These data were not tidally filtered to account for tidal effects. Although all of the data presented represent near-surface temperatures, the strength of tidal mixing is enough to ensure that bottom temperatures differ little from surface temperatures in most of the delta and much of Suisun Bay.

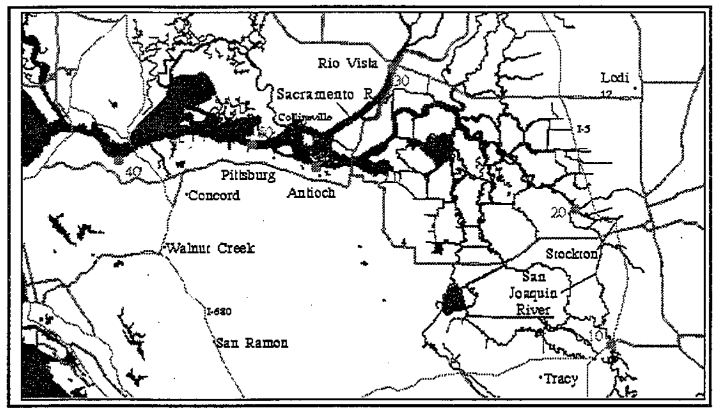

Figure 1
CONTINUOUS WATER QUALITY MONITORING SITES

Results were similar to what would be expected, with warmest temperatures during July and August (Table 1). Although 1996 temperature patterns are similar for all stations (Figures 2-7), actual temperatures did vary. For example, the Stockton Ship Channel at Burns Cutoff averaged almost 27°C during July and August, while average monthly temperature in Carquinez Strait was about 21°C at the peak.

Determining the extent of impact of water temperature on fish as they spawn, rear, and migrate through the delta is difficult. Many factors such as food availability, habitat, disease, predation, and competition interact to cause certain fish populations to decline. Singling out a primary stressor, such as elevated temperature, requires sufficient data to support such a conclusion. Therefore, the purpose of this article is to describe temperature patterns in 1996 in relation to the temperature requirements of salmon, delta smelt, and splittail. Next year we will look at long-term trends.

Table 1
1996 AVERAGE MONTHLY WATER TEMPERATURE
(Degrees Centigrade; Measured at 1-Meter Depth)

	San Joaquin River at Mossdale Crossing	Stockton Ship Channel at Burns Cutoff	Sacramento River at Rio Vista Bridge	San Joaquin River at Antioch	Carquinez Strait at Martinez	Sacramento River at Mallard Island
January	—	10.7	9.7	10.6	10.5	10.5
February	11.3	13.2	11.6	12.1	10.5	11.7
March	13.3	13.9	13.0	13.6	—	12.9
April	15.5	16.7	14.8	16.1	15.8	15.6
May	17.7	18.6	17.0	19.3	17.9	18.2
June	21.5	23.3	20.1	21.8	19.4	20.7
July	25.0	26.8	22.0	22.8	20.7	21.7
August	24.9	26.6	21.8	23.2	20.9	21.8
September	21.6	23.3	19.9	21.0	19.7	20.1
October	17.4	18.9	17.7	18.5	17.5	17.6
November	13.8	14.1	13.5	14.4	13.9	13.9
December	11.4	11.4	10.9	11.7	11.2	11.2

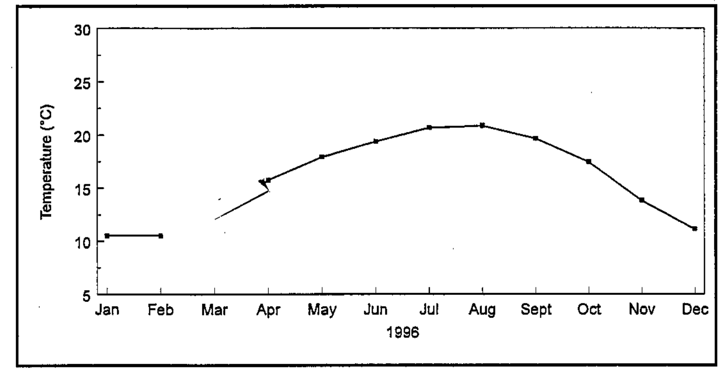

Figure 2
AVERAGE MONTHLY TEMPERATURE,
CARQUINEZ STRAIT AT MARTINEZ
Measured at 1-Meter Depth

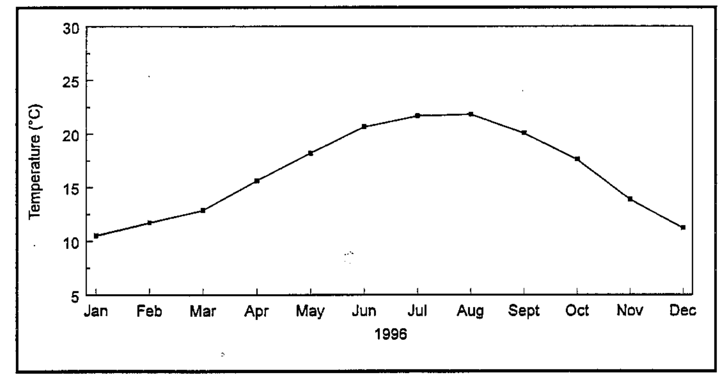

Figure 3
AVERAGE MONTHLY TEMPERATURE,
SACRAMENTO RIVER AT MALLARD ISLAND
Measured at 1-Meter Depth

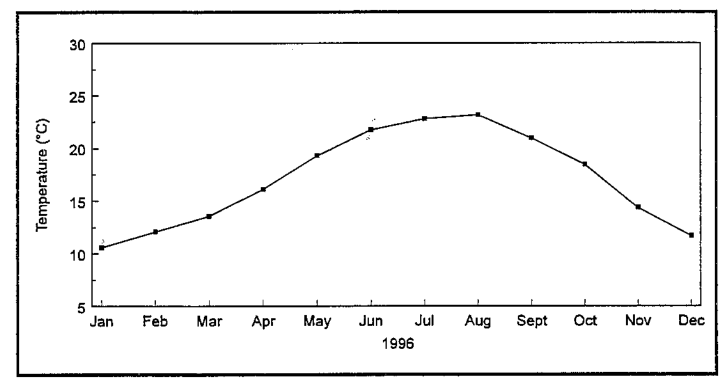

Figure 4
AVERAGE MONTHLY TEMPERATURE,
SAN JOAQUIN RIVER AT ANTIOCH
Measured at 1-Meter Depth

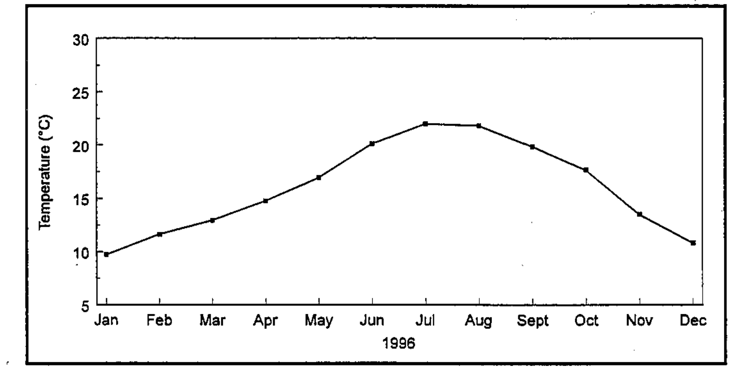

Figure 5
AVERAGE MONTHLY TEMPERATURE,
SACRAMENTO RIVER AT RIO VISTA BRIDGE
Measured at 1-Meter Depth

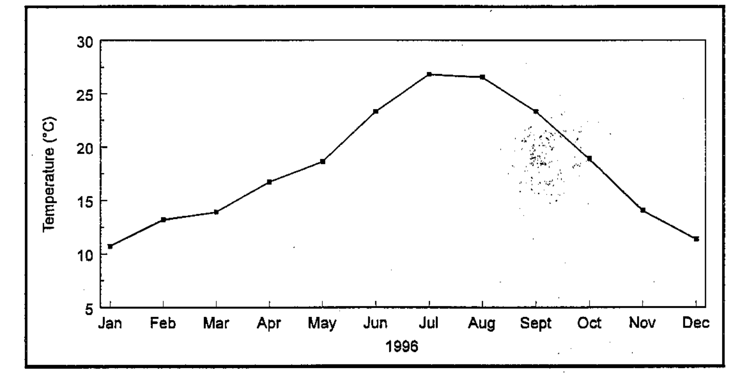

Figure 6
AVERAGE MONTHLY TEMPERATURE,
STOCKTON SHIP CHANNEL AT BURNS CUTOFF
Measured at 1-Meter Depth

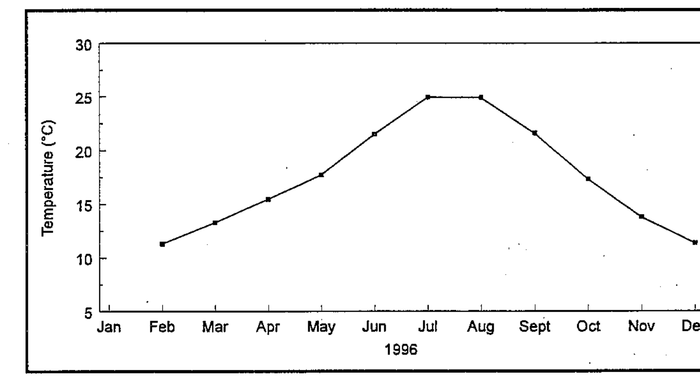

Figure 7
AVERAGE MONTHLY TEMPERATURE,
SAN JOAQUIN RIVER AT MOSSDALE CROSSING
Measured at 1-Meter Depth

The upper temperature limit for juvenile chinook salmon growth and rearing is a daily average temperature of 15.6°C; warmer temperatures are likely to lead to physiological stress and mortality (NMFS 1996). At water temperatures of 15.6-17.5°C, juvenile chinook salmon experience low sublethal chronic stress (Rich 1987). At temperatures of 17.2-20.0°C, juvenile chinook become fatigued and disoriented, and exhibit modified behavior, which makes them more susceptible to predation (Marine and Cech 1992). Juvenile chinook begin to experience immediate mortality at 23.9°C and higher (Brett 1952).

In 1996, juvenile chinook salmon, particularly fall and spring-run, were exposed to temperatures above 15.6°C during emigration through the delta. The earliest emigrating winter-run chinook (mid-July through September) and later emigrating winter-run juveniles (April through May) were also exposed to temperatures above 15.6°C in the delta. NMFS (1996) predicts that elevated water temperature in April-June could substantially affect juvenile winter-run chinook.

Elevated delta water temperature can also impede adult chinook salmon upstream migration. When exposed to temperatures of 18.3-20.6°C, adult chinook salmon may experience reduced energy for spawning, prespawning mortality, reduced gamete viability, and inability to reach the upstream migration location (NMFS 1996). In studies of fall-run chinook, adults began to experience physiological stress when exposed to water temperatures in the range of 15.0-20.0°C for prolonged periods (Marine 1992). Poor egg viability has also been found in adult fall-run chinook held in hatcheries at temperatures greater than 15.6°C (Hinze 1959). Hallock *et al* (1970) found that in the San Joaquin River, adult chinook migration ceased at temperatures above 21.1°C and resumed when temperatures decreased to 18.3°C. Diseases in adults also become exacerbated at elevated water temperature (NMFS 1996).

In 1996, San Joaquin fall-run adults migrated through the delta in August-October. At five of the six monitoring stations, August monthly temperature averaged above 21.1°C; only Carquinez Strait at Martinez averaged lower. In September, both the San Joaquin River at Mossdale Crossing and the Stockton Ship Channel at Burns Cutoff also averaged above 21.1°C. Spring-run adults migrated through the delta in April-June. Three of the six continuous monitoring stations showed average monthly June temperatures above 21.1°C. There are no data to show that elevated temperatures restricted migration; however, increased temperatures may have reduced energy, contributed to prespawning mortality, or resulted in poor egg viability.

Delta smelt of all sizes are found in the main delta channels, where the water is well oxygenated and temperature is relatively cool, usually less than 20-22°C in summer (USFWS 1995). Delta smelt spawn in the delta in January-July at about 7-15°C (Wang 1986). In recent years, however, ripe delta smelt and recently hatched larvae have been collected at 15-22°C, so it is likely that spawning can occur over the entire 7-22°C range (USFWS 1995). Optimal temperature for survival of embryos and larvae has not yet been determined, although R. Mager of UC-Davis (unpublished data) found low hatching success and embryo survival from spawns of captive fish collected at high temperatures.

During two tow-net surveys, July 8-15 and July 22-26, delta smelt were collected near four continuous water quality monitoring stations. During the tow-net sampling, water temperature in the San Joaquin River at Antioch averaged slightly above 22°C, which exceeds delta smelt typical temperature range. Notably, very few delta smelt were collected in the Antioch area. In general, fewer delta smelt were collected in areas of higher temperature than in areas of lower temperature. It is unknown whether elevated temperature played a role in restricting delta smelt distribution or if there were other controlling factors.

Splittail are found in the fresh and brackish waters of the delta year round. Adult splittail undertake an annual upstream spawning migration in autumn and winter (Caywood 1974; Meng and Moyle 1995). Cech and Young (1995) estimated water temperature for splittail preference and optimum growth. When acclimated to 17°C, young-of-the-year splittail experienced optimal growth at 21°C, and juveniles and adults had final preference and optimal growth at 20°C. The critical temperature maximum (the temperature that triggers mortality) is high for splittail. Splittail did not begin showing signs of distress until about 29°C.

In 1996, water temperature did appear to exceed splittail preference and growth optimum; however, at no time did temperature exceed the critical temperature maxima necessary to support splittail.

Overall, no studies were conducted to determine whether elevated temperatures negatively impacted fish that spawn, rear, or migrate through the delta. However, this summary of the 1996 temperature patterns indicates that some fish species, including salmon, delta smelt, and splittail, may have been directly or indirectly affected.

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USGS Water Quality Data for San Francisco Bay Now on the World Wide Web
http://sfbay.wr.usgs.gov/access/wqdata/index.html

Each month the U.S. Geological Survey makes water quality measurements in San Francisco Bay, from the southern limit of South Bay to the Sacramento River at Rio Vista. Results of this measurement program are displayed and explained at this website. The site is organized around four topics:

→ Description of the sampling program.

→ Results from sampling cruises, displayed as color images.

→ Summaries of measurements made in recent years, showing annual cycles of water quality variability.

→ Results from the full history of USGS San Francisco Bay water quality studies, beginning in 1968.

New Technical Reports

Only one Interagency Technical Report has been released since the last *Newsletter*. Copies of this one are limited, but if you would like one, please contact Lisa at 916/227-7541 or lbatiste@ cd-eso.water.ca.gov.